

# Development of a Small Telescope like PZT and Effects of Vibrations of Mercury Surface and Ground Noise

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**Abstract**—A PZT type telescope for observations of gravity gradient and lunar rotation was developed, and a Bread Board Model (BBM) for ground experiments was completed. Some developments were made for the BBM such as a tripod with attitude control system, a stable mercury pool and a method for collecting the effects of vibrations. Laboratory experiments and field observations were performed from August to September of 2014, in order to check the entire system of the telescope and the software, and the results were compared to the centroid experiments which pursue the best accuracy of determination of the center of star images with a simple optical system. It was also investigated how the vibrations of mercury surface affect the centroid position on Charge Coupled Device (CCD). The results of the experiments showed that the effects of vibrations are almost common to stars in the same view, and they can be corrected by removing mean variation of the stars; and that the vibration of mercury surface can cause errors in centroid as large as 0.2 arcsec; and that there is a strong correlation between the Standard Deviation (SD) of variation of the centroid position and signal to noise ratio (SNR) of star images. It is likely that the accuracy of one (1) milli arcsecond is possible if SNR is high enough and the effects of vibrations are corrected.

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## INTRODUCTION

Photographic Zenith Tube (PZT) is a kind of positioning telescope which was developed more than 100 years ago, and it can observe not only latitude but longitude because it measures both zenith distance and hour angle of stars when they pass the meridian near the zenith. Thus, the PZT had long been used for observations of Earth rotation as one of major telescopes in the International Latitude Service (ILS) and the International polar motion service (IPMS) [1]. It was looked at again after Charge Coupled Device (CCD) was used as a sensor instead of a photographic plate. Hirt and Bürki [2] developed a transportable digital zenith camera which is similar to the PZT for automated determination of deflection of the vertical (DOV), and attained the accuracy of 0.1 to 0.15 arcseconds in field observations. This accuracy is comparable to that of the Earth rotation with stationary large PZTs [1]. It was also shown that PZT could be applied

to field observations by taking the advantage of tilt compensation mechanism.

The latitude  $\psi$  and longitude  $\lambda$  components of DOV ( $\xi$ ,  $\eta$ ) are obtained by differentiating geoidal height ( $N_g$ ) as,

$$\xi = -(1/r)(\partial N_g / \partial \psi), \quad (1)$$

$$\eta = -(1/r \cos \psi)(\partial N_g / \partial \lambda), \quad (2)$$

with geographical latitude  $\psi$  [3]. These equations show that the geoidal height can be obtained from the DOV, and vice versa. Li et al [4] succeeded in detecting the variation of DOV in Beijing with the accuracy better than 0.05 arcseconds from the gravity surveys made at the network along the area. On the contrary, it is easy to imagine that we can detect gravity change by DOV observations if the accuracy is high enough.

On the other hand, observation of lunar rotation using a telescope like PZT set on the Moon was pro-